The invention relates to a system for actuating a member and also to methods of actuating a member using such a system.

The invention also relates to the use of such a system for actuating a device for metering fuel in a heat engine, in particular in an aeronautical turbine engine.

In the context of this use, it is known to use an actuating system comprising an electric motor, for example of the stepping type, which comprises a device for transmitting the movement of the electric motor to a valve for supplying fuel to the heat engine. The electric motor is controlled by a computer that is designed to regulate the current with which the electric motor is supplied as a function of a position setpoint of the valve which is derived from the acceleration command actuated by the pilot, so as to supply the heat engine with the desired amount of fuel.

It has been proposed to make such an actuation safer by comparing the actual movement of the electric motor and the

movement that corresponds in theory to the applied setpoint, so as to detect in real time any actuation anomaly.

To do this, it has been proposed to measure the actual movement of the electric motor using a sensor of the resolver type which delivers information about the absolute angle of the rotor of the electric motor in the form of analogue signals.

The integration of this type of sensor in an actuating system poses many problems. This is because sensors of the resolver type are particularly bulky and heavy on account of the technology with which they are produced, which requires a rotor and a stator that may be composed of a number of windings formed of wires wound around a metal carcass. Moreover, the volume needed for their integration often requires them to be mounted on a rotor parallel to that of the electric motor. Consequently, particularly in the case of small actuating systems, the sensor becomes as bulky as the electric motor and significantly contributes to the total mass of the actuating system.

Furthermore, since the position information delivered is of an analogue nature, the actuating system must comprise an analogue/digital conversion stage at the input of the computer so as to be able to make use of said information.

Moreover, particularly in the context of the use under consideration, it is indispensable to obtain reliable and precise actuation, and to do so under use conditions that are severe in terms of vibrations, temperatures and pressures.

Sensors of the resolver type, particularly on account of the large number of elements of which they are composed and the presence of an additional analogue/digital conversion stage

within the computer, do not optimally satisfy these constraints, particularly in terms of reliability.

The same is true of sensors of the resistive type, the reliability of which is highly affected by severe use conditions.

The invention aims to solve all of the problems mentioned above by proposing in particular an actuating system which has means that deliver, in a precise and reliable manner, position information that is representative of the movements of the electric motor, said information being in the form of digital signals and it being possible for said means to be easily integrated in the actuating system.

For this purpose, and according to a first aspect, the invention proposes an actuating system of the type comprising an electric motor controlled by a computer that is designed to regulate the current supplied to the electric motor as a function of a position setpoint of the member that is to be actuated, said system comprising a device for transmitting the movement of the electric motor to the member, in which the transmission device comprises an encoder that is dependent on the movement of the electric motor, said encoder comprising a main multipolar track, and the system comprising:

- a fixed sensor comprising at least two sensitive elements that are arranged facing and at an air-gap distance from the main track, said sensor being designed to deliver two square digital position signals A, B in quadrature which are representative of the position of the encoder;

- a device for processing the signals A, B, which device comprises counting means for determining, from an initial position, the actual position of the encoder;

- a device for comparing the actual position of the encoder with the position of the encoder that corresponds in theory to the applied setpoint.

According to one embodiment, the comparison device comprises alert means which, upon determination of a significant difference between the actual position and the theoretical position, are designed to emit a signal indicating an anomaly in the operation of the actuating system.

According to a second aspect, the invention proposes a method of actuating a member using such an actuating system, which method comprises the provident iterative steps of:

- applying to the computer a position setpoint of the member;

- determining the actual position of the encoder;

- comparing the actual position of the encoder with the position of the encoder that corresponds in theory to the applied setpoint;

- if the difference between the actual position and the theoretical position is greater than a threshold, activating the alert means.

According to another embodiment, the comparison device comprises an actuation feedback loop, which is controlled as a function of the determined difference between the actual position and the theoretical position.

According to a third aspect, the invention proposes a method of actuating a member using such an actuating system, which method comprises the provident iterative steps of:

- applying to the computer a position setpoint of the member;

- determining the actual position of the encoder;

- comparing the actual position of the encoder with the position of the encoder that corresponds in theory to the applied setpoint;

- if the difference between the actual position and the theoretical position is greater than a threshold, controlling the feedback loop so as to apply to the computer a position setpoint that is slaved to the difference.

According to a fourth aspect, the invention proposes the use of an actuating system according to the invention for actuating a device for metering fuel in a heat engine.

Other objects and advantages of the invention will emerge from the following description, given with reference to the appended drawings, in which:

- figures 1 and 2 are functional diagrams of a system for actuating in rotation respectively according to a first and a second embodiment of the invention;

- figures 3a and 3b are functional diagrams of a system for actuating in translation according to one embodiment of the invention, respectively seen perpendicular and parallel to the axis of actuation;

- figure 4 is a view in longitudinal section of an actuating system for a device for metering fuel in a heat engine;

- figure 5 is a view in section on line V-V of figure 4.

The invention relates to an actuating system comprising an electric motor 1, for example of the stepping type, which is

controlled by a computer 2 that is designed to regulate the current supplied to the motor 1 as a function of a setpoint.

The system is intended to actuate a member via a device for transmitting the movement of the motor 1 to said member. The actuation is then obtained by controlling the motor 1 with a position setpoint of the member that is to be actuated, said setpoint being designed, depending on the nature of the transmission device, to move the member into the desired position.

In one particular use, the system is intended to actuate a device for metering fuel in a heat engine, in particular an aeronautics turbine. For this purpose, the transmission device makes it possible to actuate a valve for supplying fuel to the heat engine, and the setpoint is derived from the acceleration command which is actuated by the pilot.

In order to know the actual movement of the transmission device that is induced by the setpoint, the invention proposes integrating into the actuating system an encoder 3 provided with a main multipolar track that is dependent on the movement of the motor 1, and a sensor 4 that can deliver two digital signals which are representative of the position of said encoder and hence of the movements of the electric motor 1.

In one particular example, the encoder 3 is formed of a multipolar magnetic part on which there is magnetized a plurality of pairs of north and south poles equally distributed with a constant angular width so as to form the main track. In one example of embodiment, the encoder 3 is formed of an elastomeric part which is charged with magnetic particles, for example with ferrite such as barium ferrite or strontium ferrite.

The sensor 4 is fixed and comprises at least two sensitive elements that are arranged facing and at an air-gap distance from the main track, so as to deliver two periodic electrical signals S1, S2 in quadrature. The sensor 4 also comprises means for digitizing the signals S1, S2 so as to deliver two square digital position signals A, B in quadrature which are representative of the position of the encoder 3.

In one particular example, the sensitive elements are chosen from the group comprising Hall probes, magnetoresistors and giant magnetoresistors.

The principle of obtaining the signals S1 and S2 from a plurality of aligned sensitive elements is described for example in the document FR-2 792 403 by the Applicant. In particular, this embodiment makes it possible to obtain position signals which do not depend on the amplitude of the read magnetic field and which are therefore insensitive to the air-gap variations due to the movement of the encoder 3 and also to the decrease in the magnetic field due to the temperature.

However, sensors 4 comprising two sensitive elements that can deliver the signals S1 and S2 are also known.

According to one embodiment, described for example in the document FR-2 754 063 by the Applicant, the sensor 4 comprises means for interpolating the signals which make it possible to increase the resolution of the output digital signals A, B so as to be able to use a smaller number of pairs of poles. Thus, it is possible to use a high level of magnetic induction, and this makes it possible to increase on the one hand the robustness of operation of the actuating system with respect to the severe use conditions and on the

other hand the resolution of the position signals, and to do so without increasing the bulk of the encoder 3.

The actuating system furthermore comprises a device 5 for processing the signals A, B, which device comprises counting means for determining, from an initial position, the actual position of the encoder 3.

In one example of embodiment, the counting means comprise a register in which the value of the position of the encoder 3 is incremented or decremented by a value corresponding to the number of fronts of the signals A, B that are detected.

The sensor 4 and the processing device 5 may be integrated on a silicon substrate or the like, for example an AsGa substrate, so as to form an integrated circuit that is customized for a specific application, which circuit is sometimes referred to as an ASIC to denote an integrated circuit that is designed in whole or in part as a function of requirements.

According to a first embodiment, the initial position is fixed at zero when the actuating system is set in operation. Thus, the processing device 5 makes it possible to know the relative position of the encoder 3 with respect to the initial position, that is to say the distance separating the position of the encoder 3 from any initial position, which may vary with respect to a fixed referential.

According to a second embodiment, the processing device 5 is designed to deliver the absolute position of the encoder 3. The term absolute position is understood to mean the distance separating the position of the encoder 3 at a given instant from a reference position of the encoder 3, this reference position being fixed and given with respect to a fixed referential. For this purpose, the system comprises

means for determining a reference position and the processing device 5 comprises means which, upon detection of said reference position, can assign said reference position as initial position.

According to a first embodiment, the means for determining the reference position are integrated in the encoder 3. For this purpose, the encoder 3 furthermore comprises a singularity that is indexed to a reference position of the encoder 3, and the sensor furthermore comprises at least one sensitive element designed to detect said singularity. In particular, the encoder 3 may comprise a multipolar track that is referred to as the "top tour" track, said track being provided with the singularity, at least one sensitive element being arranged facing and at an air-gap distance from said "top tour" track so as to deliver a digital signal C that comprises a pulse. The processing device 5 then comprises means which, upon detection of the pulse, can assign the reference position as initial position. One principle of obtaining the digital signals A, B and C, and also various ways of realizing a magnetic singularity, are described in the documents FR-2 769 088 and EP-0 871 014. In particular, the magnetic singularity of the "top tour" track may be formed of two adjacent poles the magnetic transition of which is different from the others.

According to a second embodiment, the means for determining the reference position are integrated in the transmission device. For this purpose, the transmission device may comprise a stop that is designed to interrupt the movement of the motor 1 in a reference position of the encoder 3, and the processing device 5 may comprise means which, upon interruption of the movement, can assign the reference position as initial position.

Although the description is given in relation to an encoder/magnetic sensor assembly, it is also possible to implement the invention analogously using an equivalent technology, for example of the optical type. For example, the encoder 3 may be formed of a metal or glass target on which the main track and possibly the "top tour" track have been engraved so as to form an optical motif that is analogous to the multipolar magnetic motif described above, the sensitive elements then being formed of optical detectors.

The actuating system furthermore comprises a device 6 for comparing the actual position of the encoder 3, that is to say the position determined by the processing device 5, with the position of the encoder 3 that corresponds in theory to the applied setpoint. The comparison device 6 thus makes it possible to make the actuation safer by verifying in real time the correspondence between the movements of the electric motor 1 and the setpoint applied to the computer 2.

In one particular example, the comparison device 6 is integrated in the computer 2 and comprises a comparator for making a comparison between the position signal coming from the processing device 5 and the position signal derived from the setpoint, the integration being particularly simple and reliable on account of the digital nature of the two types of signal.

According to a first embodiment, the comparison device 6 comprises alert means which, upon determination of a significant difference between the actual position and the theoretical position, are designed to emit a signal, for example a light signal or audible signal, indicating an anomaly in the operation of the actuating system.

The method of actuating the member using such an actuating system then comprises the provident iterative steps of:

- applying to the computer 2 a position setpoint of the member;
- determining the actual position of the encoder 3;
- comparing the actual position of the encoder 3 with the position of the encoder 3 that corresponds in theory to the applied setpoint;
- if the difference between the actual position and the theoretical position is greater than a threshold, activating the alert means.

According to a second embodiment, the comparison device 6 comprises, possibly in addition to the alert means, an actuation feedback loop, which is controlled as a function of the determined difference between the actual position and the theoretical position. Thus, any anomaly in the operation of the actuating system can be corrected by controlling the system in real time so as to position the encoder 3 in the position corresponding to the setpoint. As a variant, the processing device 5 may also be able to deliver signals which are representative of the speed of displacement of the encoder 3, it being possible for said signals to be used in the feedback loop.

The method of actuating the member using such an actuating system then comprises the provident iterative steps of:

- applying to the computer 2 a position setpoint of the member;
- determining the actual position of the encoder 3;

- comparing the actual position of the encoder 3 with the position of the encoder 3 that corresponds in theory to the applied setpoint;

- if the difference between the actual position and the theoretical position is greater than a threshold, controlling the feedback loop so as to apply to the computer 2 a position setpoint that is slaved to the difference.

In the two embodiments described above, the method may where appropriate comprise a prior procedure of determining the initial position of the encoder 3. In particular, when the actuating system is set in operation, the procedure may envisage supplying the motor 1 with current so as to position the encoder 3 in its reference position, said reference position being assigned in the processing device 5 as initial position, so as to subsequently determine the absolute position of the encoder 3.

With reference to figures 1 and 2, a description is given of a system for actuating a member in rotation.

According to the embodiment of figure 1, the transmission device comprises the rotor 7 of the electric motor 1, the encoder 3 being mounted on a part of said rotor that is opposite the member that is to be actuated.

According to the embodiment of figure 2, the transmission device comprises a two-stage reducer 8, the encoder 3 being mounted on the output rotor 9 of said reducer. As a variant, the encoder 3 may also be mounted on the rotor 7 of the electric motor 1 or on the input rotor 10 of the reducer 8.

In these two embodiments, the encoder 3 and hence the multipolar tracks are circular, said encoder being for

example annular in shape and comprising a bore that allows it to be connected to the rotor 7, 9.

With reference to figures 3a and 3b, a description is given of a system for actuating a member in translation. For this purpose, the transmission device comprises the rotor 7 which is provided with a pinion 11 and a part 12 provided with a rack 13, which are designed to transform the rotary movement of the rotor 7 into a linear movement of the part 12, the encoder 3 being associated with said part. As a variant, the part 12 may form part of the member that is to be actuated.

In this embodiment, the encoder 3 and hence the multipolar tracks are linear, said encoder being for example moulded with the part 12.

With reference to figures 4 and 5, a description is given of an actuating system for a device for metering fuel in a heat engine, which corresponds to the functional diagram of figure 2. For this purpose, the output rotor 9 comprises a slot into which there is designed to be inserted the valve for supplying fuel to the metering device (not shown).

The actuating system comprises a casing 14 in which the motor 1 and the reducer 8 are housed so as to form a single assembly.

The encoder 3 is fixed to an annular journal 15 of the gear wheel 16 which is associated with the output rotor 9. This embodiment makes it possible to integrate an encoder 3 having a large diameter, which makes it possible to improve the precision with which the position of said encoder is measured without increasing the size of the actuating system or requiring additional mechanical parts.

The sensor 4 is formed of a non-magnetic structural part in which the sensitive elements and the associated electronics

are housed, the input/output connection of the sensor, which is formed of a multiconductor cable 17, projecting from said part so as to allow in particular the connection of said sensor to the computer 2.

The non-magnetic structural part comprises a head 4a on a side face of which there extends a body 4b, the sensitive elements being disposed in the vicinity of the free side face 4c of the body 4b and the cable 17 extending from the side face of the head 4a that is opposite the body 4b. The part is designed so that the head 4a has, on the body side, a free side surface 4d.

The sensor 4 is fixed in a housing 18 of the casing 19 of the reducer 8, said housing being designed to receive the body 4b by pressing the free side surface 4d against the peripheral wall of said housing. Thus, the sensitive elements are placed precisely and reliably facing and at an air-gap distance from the encoder 3 so as to be able to withstand the severe use conditions. Furthermore, a wedge 20 may be placed between the peripheral wall of the housing and the free side surface 4b so as to be able to regulate the air-gap distance.